Fischer, H. (1966): Secondary sex ratio in the water buffalo *(Bubalus bubalis).* Z. Tierzüchtg. Züchtgsbiol. **82,** 361–363.
Geissler, A. (1889): Beiträge zur Frage des Geschlechterverhältnisses der Geborenen. Z. kgl. sächs. statist. Bureau **35,** 1–24.
Gill, J. L. (1985): Interpretation of significance in testing multiple traits. J. Anim. Sci. **60,** 867–870.
Gini, C. (1951): Combinations and sequences of sexes in human families and mammal litters. Acta genet. statist. med. **2,** 220–244.
Gosling, L. M. (1986a): Selective abortion of entire litters in the coypu: adaptive control of offspring production in relation to quality and sex. Amer. Nat. **127,** 772–795.
— (1986b): Biased sex ratios in stressed animals. Amer. Nat. **127,** 893–896.
Grakov, N. I. (1969): Polovaja, vozrastnaja struktura i prirost populjacii lesnoj kunicy (Sex and age structure and population growth in the pine marten). In: Voprosy ėkologii promyslovych životnych (Questions of the ecology of game animals). Kirov: VNIIŽP. pp. 3–18.
Gray, E.; Bortolozzi, J. (1977): Studies of the human sex ratio and factors influencing family size in Botucatu, Brazil. J. Hered. **68,** 241–244.
Gray, E.; Hurt, V. K. (1979): Distribution of sexes in cattle. J. Hered. **70,** 273–274.
Gray, E.; Katanbaf, M. N. (1985): Sex ratio and distribution of sexes in swine. J. Hered. **76,** 36–38.
Gray, E.; Morrison, N. M. (1974): Influence of combinations of sexes of children on family size. J. Hered. **65,** 169–174.
Groves, C. P. (1974): Horses, asses, and zebras in the wild. Hollywood: Curtis Books.
Harmsen, R.; Cooke, F. (1983): Binomial sex-ratio distribution in the lesser snow goose: a theoretical enigma. Amer. Nat. **121,** 1–8.
James, W. H. (1975): The distributions of the combinations of the sexes in mammalian litters. Genet. Res. **26,** 45–53.
— (1976): Timing of fertilization and sex ratio of offspring. A review. Ann. Human Biol. **3,** 549–554.
— (1983): Timing of fertilization and the sex ratio of offspring. In: Sex selection of children. Ed. by N. G. Bennett. Orlando: Academic Press. pp. 73–100.
Kamaljan, V. Š. (1962): Vlijanie vozrasta roditelej na sootnošenie pola potomstva (Effect of the parental age on the sex ratio of offspring). Ž. obšč. Biol. **23,** 455–459.
Keiper, R. R. (1979): Population dynamics of feral ponies. In: Symposium on the ecology and behavior of wild and feral equids. Ed. by R. H. Denniston. Laramie: Univ. Wyoming. pp. 175–184.
Kennedy, B. W.; Moxley, J. E. (1978): Genetic and environmental factors influencing litter size, sex ratio and gestation length in the pig. Anim. Product. **27,** 35–42.
Klat, M. (1983): Sex of children and family size: a decision model. Math. Biosci. **65,** 171–185.
Koročkina, L. N. (1968): Faktory, vlijajuščie na sootnošenie pola u zubrov (Factors influencing sex ratio in bisons). Belovežskaja pušča (Beloveža forest) **2,** 139–147.
Labov, J. B.; Huck, U. W.; Vaswani, P.; Lisk, R. D. (1986): Sex ratio manipulation and decreased growth of male offspring of undernourished golden hamsters *(Mesocricetus auratus).* Behav. Ecol. Sociobiol. **18,** 241–249.
Lowe, V. P. W. (1969): Population dynamics of the red deer (*Cervus elaphus* L.) of Rhum. J. anim. Ecol. **38,** 425–457.
Loyd, R. C.; Gray, E. (1969): A statistical study of the human sex ratio. J. Hered. **60,** 329–331.
Maynard Smith, J. (1977): Parental investment: a prospective analysis. Anim. Behav. **25,** 1–9.
— (1980): A new theory of sexual investment. Behav. Ecol. Sociobiol. **7,** 247–251.
McClure, P. A. (1981): Sex-biased litter reduction in food-restricted wood rats *(Neotoma floridana).* Science **211,** 1058–1060.
McCort, W. D. (1979): The feral asses *(Equus asinus)* of Ossabau Island, Georgia: mating system and the effect of vasectomies as a population control procedure. In: Symposium on the ecology and behavior of wild and feral equids. Ed. by R. H. Denniston. Laramie: Wyoming. pp. 71–83.
McGinley, M. A. (1984): The adaptive value of male-biased sex ratios among stressed animals. Amer. Nat. **124,** 597–599.
McHugh, T. (1958): Social behavior of the American buffalo *(Bison bison).* Zoologica **43,** 29–32.
Mlíkovský, J. (1985): Sex ratio distribution in the Siberian tiger *Panthera tigris altaica* (Mammalia: Felidae). Z. Säugetierkunde **50,** 47–51.
— (1987): On the relationship between the secondary sex ratio and parental age in man. Acta Univ. Carol. (Med.), (in press).
Mohr, E.; Volf, J. (1984): Das Urwildpferd *Equus przewalskii.* Wittenberg Lutherstadt: A. Ziemsen Verlag.
Myers, J. H. (1978): Sex ratio adjustment under food stress: maximization of quality or number of offspring? Amer. Nat. **112,** 381–388.
Myers, P.; Master, L. L.; Garrett, R. A. (1985): Ambient temperature and rainfall: an effect on sex ratio and litter size in deer mice. J. Mammalogy **66,** 289–298.
Nelson, K. J. (1980): Sterilization of dominant males will not limit feral horse populations. U.S.D.A., For. Serv. Res. Pap. RM-226.

Paul, A.; Thommen, D. (1984): Timing of birth, female reproductive success and infant sex ratio in semi-free-ranging Barbary macaques *(Macaca sylvanus).* Folia primatol. **42,** 2–16.
Penzhorn, B. L. (1975): Behaviour and population ecology of the Cape mountain zebra, *Equus zebra zebra* L., 1758, in the Mountain Zebra National Park. Unpubl. PhD. thesis, Univ. Pretoria.
Pollard, G. N. (1969): Factors influencing the sex ratio at birth in Australia, 1902–1965. J. biol. Sci. **1,** 125–144.
Rawlins, R. G.; Kessler, M. J. (1986): Secondary sex ratio variation in the Cayo Santiago macaque population. Amer. J. Primatol. **10,** 9–23.
Renkonen, K. O. (1956): Is the sex ratio between boys and girls correlated to the sex of precedent children? Ann. Med. exp. Fenn. **34,** 447–451.
Rivers, J. P. W.; Crawford, M. A. (1974): Maternal nutrition and the sex ratio at birth. Nature **252,** 297–298.
Rutberg, A. T. (1986): Lactation and fetal sex ratios in American bison. Amer. Nat. **127,** 89–94.
Sachs, L. (1974): Angewandte Statistik. Berlin: Springer-Verlag.
Schützenberger, M. P. (1949): Resultats d'une enquête sur la distribution du sexe dans les familles nombreuses. Sem. Hôp. Paris **25,** 2579–2582.
— (1950): Nouvelles recherches sur la distribution du sexe à la naissance. Sem. Hôp. Paris **26,** 4458–4465.
Silk, J. B. (1983): Local resource competition and facultative adjustment of sex ratios in relation to competitive abilities. Amer. Nat. **121,** 56–66.
Silk, J. B.; Clark-Wheatley, C. B.; Rodman, P. S.; Samuels, A. (1981): Differential reproductive success and facultative adjustment of sex ratios among captive female bonnet macaques *(Macaca radiata).* Anim. Behav. **29,** 1106–1120.
Simpson, M. J. A.; Simpson, A. E. (1982): Birth sex ratios and social rank in rhesus monkey mothers. Nature **300,** 440–441.
Skogland, T. (1986): Sex ratio variation in relation to maternal condition and parental investment in wild reindeer *Rangifer t. tarandus.* Oikos **46,** 417–419.
Smith, C. C.; Fretwell, S. D. (1974): The optimal balance between size and number of offspring. Amer. Nat. **108,** 499–506.
Smuts, G. L. (1976): Population characteristics of Burchell's zebra (*Equus burchelli antiquorum,* H. Smith, 1841) in the Krueger National Park. S. Afr. J. Wildl. Res. **6,** 99–112.
Sokal, R. R.; Rohlf, F. J. (1969): Biometry. San Francisco: Freeman.
Suntzeff, V.; Cowdry, E. V.; Nixon, B. B. (1962): Influence of maternal age on offspring in mice. J. Gerontol. **17,** 2–7.
Trivers, R. L. (1972): Parental investment and sexual selection. In: Sexual selection and the descent of man, 1871–1971. Ed. by B. G. Campbell. Chicago: Aldine. pp. 137–179.
Trivers, R. L.; Willard, D. E. (1973): Natural selection of parental ability to vary the sex ratio of offspring. Science **179,** 90–92.
Van der Merwe, M.; Skinner, J. D. (1982): Annual reproductive pattern in the dassie *Procavia capensis.* S. Afr. J. Zool. **17,** 130–135.
Verme, L. J. (1983): Sex ratio variation in *Odocoileus:* a critical review. J. Wildl. Manage. **47,** 573–582.
— (1985): Progeny sex ratio relationships in deer: theoretical vs. observed. J. Wildl. Manage. **49,** 134–136.
Verme, L. J.; Ozoga, J. J. (1981): Sex ratio of white-tailed deer and the estrus cycle. J. Wildl. Manage. **45,** 710–715.
Volf, J. (1980): Generální plemenná kniha koní Převalského – General pedigree book of the Przewalski horse. Praha: Zoo Praha.
— (1981–1984): Plemenná kniha koní Převalského – Pedigree book of the Przewalski horse. Praha: Zoo Praha.
Wald, A.; Wolfowitz, J. (1940): On a test whether two samples are from the same population. Ann. math. Statist. **11,** 147–162.
Welsh, D. A. (1975): Population, behavioural, and grazing ecology of the horses of Sable Island, Nova Scotia. Unpubl. PhD. thesis, Dalhousie Univ.
Williams, G. C. (1979): The question of adaptive sex ratio in outcrossed vertebrates. Proc. roy. Soc., London, (B) **205,** 567–580.
Woolf, B. (1957): The log likelihood ratio test (the G-test). Methods and tables for tests of heterogeneity in contingency tables. Ann. Human Genet. **21,** 397–409.
Zablockij, M. A. (1957): Nekotorye biologičeskie osobennosti zubra i ich izmenenija v uslovijach zagonnogo soderžanija (Some biological peculiarities of the bison and their changes in captivity). Tr. prioksko-terrasnogo Zapoved. **1,** 144–156.
Žegalov, S. B. (1950): Zakonomernosti nasledovanija pola u životnych (Regularities of the sex inheritance in animals). Usp. sovr. Biol. **30,** 130–144.

Author's address: Dr. Jiří Mlíkovský, Department of Evolutionary Biology, Czechoslovak Academy of Sciences, Sekaninova 28, CS-120 00 Praha 2, Czechoslovakia

Z. Säugetierkunde 53 (1988) 102–107

ISSN 0044-3468

The karyotype of the European roe deer *(Capreolus capreolus* L.)

By S. Herzog

Receipt of Ms. 26. 1. 1987

Abstract

The karyotype of the European roe deer (*Capreolus capreolus* L.) is described by means of G- and C-banding techniques. A standardized idiogram (diagram, ordering of the chromosomes and designation of the bands) is proposed for the species *Capreolus capreolus* L., using the idiogram of the investigated Central European animals as an example.

Introduction

Previous investigations on the karyotype of *Capreolus capreolus* L. used orcein staining (Gustavsson 1965; Amrud and Nes 1966; Herzog and Höhn 1967; Wurster and Benirschke 1967; Gustavsson and Sundt 1968; Hsu and Benirschke 1968).

A chromosone number of 2n = 70, XX resp. XY was found. All 68 autosomes are designated as acrocentric, the X-chromosome submetacentric and the Y-chromosome subtelocentric. Amrud and Nes (1966) call the Y "apparently submetacentric".

A supernumerary submetacentric chromosome was detected by Herzog and Höhn (1967) in one specimen. The authors explained this phenomenon by a double trisomy, occurring as a centric fusion. More recently, banding techniques which allow to differentiate between single chromosomes were used by Neitzel (1982) for the investigation of the Siberian roe deer (subspecies *Capreolus capreolus pygargus*). She studied three specimens and found a chromosome number between 2n = 76 and 80, dependent on a varying number of microchromosome pairs. Similar results have been obtained by Sokolov et al. (1978), Stubbe and Passarge (1979), and Stubbe (1979), using orcein staining techniques.

In the European roe deer, a karyotype analysis by means of modern banding techniques as well as a systematic description of the bands of each chromosome in accordance with an international standard is still lacking. The purpose of the present paper is to study the karyotype of the Central European roe deer by means of G- and C-banding techniques and to propose an idiogram, thereby describing the single chromosomes in accordance with the International System for Human Cytogenetic Nomenclature (ISCN 1985), to set up a basis for further investigations, especially on homologisation of karyotypes between different taxa and studies concerning karyotype evolution.

Material and methods

In order to obtain the metaphase chromosomes, tissue cultures (kidney, skeletal muscle and testes) of 69 specimens from Hessen (Bundesrepublik Deutschland) were laid out using standard culture techniques. The metaphase chromosomes were studied by modified G- and C-banding techniques (Sumner et al. 1971; Seabright 1972) and photographed with a 1000-fold magnification under oil immersion. In order to obtain a homogeneous degree of condensation in the G-banded chromosomes, only metaphases exhibiting nine G-bands on the X-chromosome (three on the short arm and six on the long arm) were taken into consideration.

Fig. 1. G-banded idiogram of a male European roe deer (*Capreolus capreolus* L.)

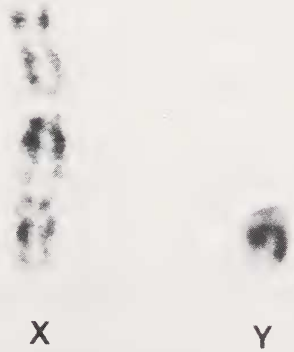


Fig. 2. Gonosomes (X and Y) of the European roe deer (*Capreolus capreolus* L.)

Table. Arm-length-ratio in the X-chromosome of *Capreolus capreolus* L., revealed by measurements of 26 haploid chromosome sets

Arm	relative length* ($\bar{x}$)	standard deviation (s_x)
p-arm	2.19	0.30
q-arm	3.00	0.39

* as percentage of the total length of the haploid autosome set.

Fig. 3. Chromosome length in *Capreolus capreolus* L. (r. L. = relative length in percent of the total haploid autosome set)

Results

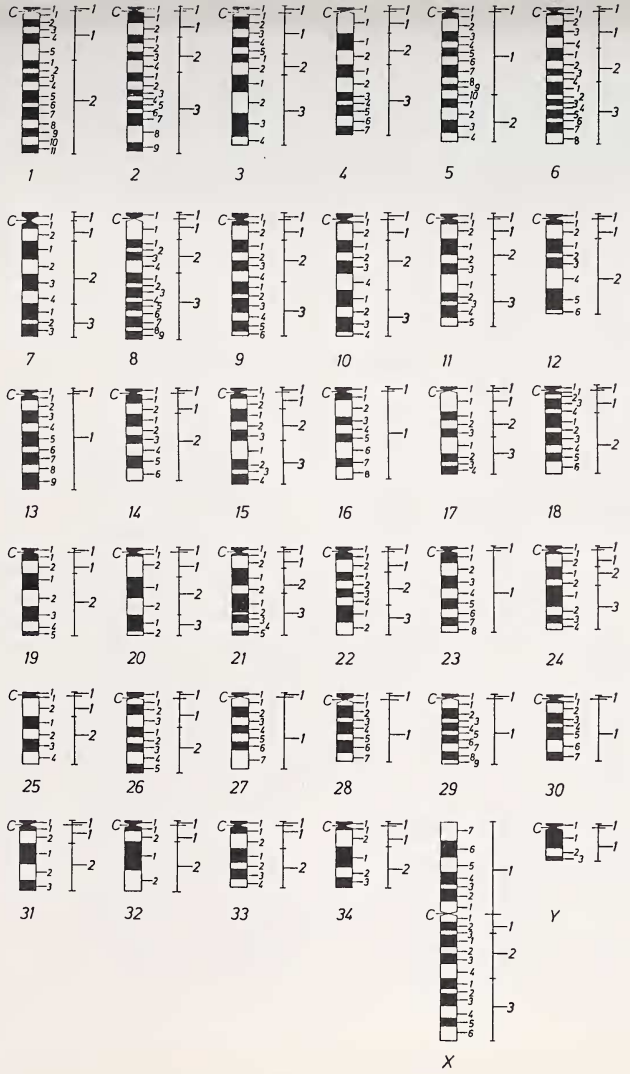
The somatic, diploid chromosome set of all 69 animals studied consists of 70 chromosomes, namely 68 autosomes and two gonosomes (2n = 70, XX resp. XY; figs. 1 and 2).

Measurements of the chromosome lengths show that all autosome pairs and the Y-chromosome are telocentric (according to the terminology of Nagl 1980) with an arm-length ratio less than 1:4. The female gonosome is subtelocentric (see table). Using high-quality preparations, short (p-)arms are obvious in all telocentric chromosomes. Thus, the Nombre fondamental (N. F.) is 140 if these short arms are taken into account, whereas it is 72 in the female and 71 in the male if the short p-arms are neglected.

The autosomal N. F. (N. F.a) is 68 resp. 136 in both male and female.

The centromeric index (c.i.) is not useful for the characterization of the chromosomes, because the p-arms of the telocentrics are not unequivocally measurable and chromosome lengths of the related chromosome pairs show only slight differences (fig. 3), mostly less than the standard deviation of the chromosome length of the relevant pairs.

Therefore it seems indispensable to use banding patterns as a tool for identification of the individual homologous chromosomes. Fig. 4 shows a proposal for the idiogram of *Capreolus capreolus* L. The bands and landmarks are drawn from the photos of the chromosomes of all 69 deer following the ISCN (1985). All autosomes exhibit distinct C-bands of different size. The euchromatin of a single autosome becomes stained over the whole length after C-banding treatment (facultative heterochromatin, fig. 5). The gonosomes show no visible C-bands, but in the female, one of the two X-chromosomes also exhibits facultative heterochromatin (sexchromatin), a phenomenon which is well known in other species, especially mammals. The occurrence of facultative heterochroma-



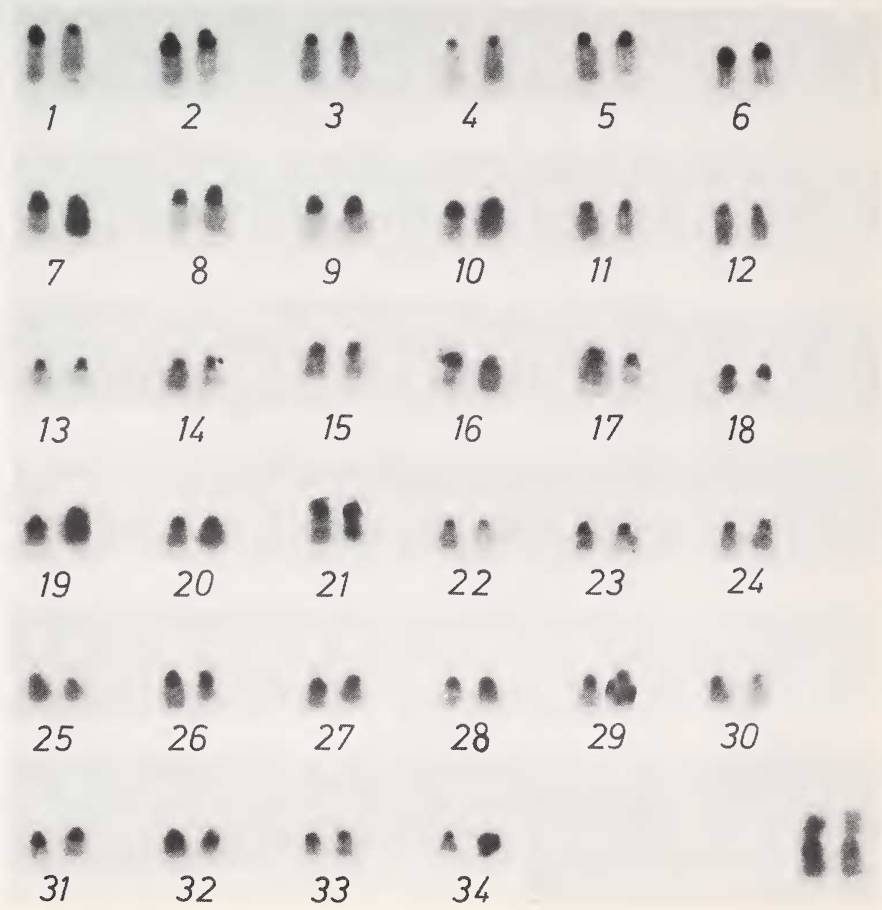


Fig. 4 (left). Proposition for a standard idiogram of *Capreolus capreolus* L. following the ISCN (1985): big numbers = landmarks, small numbers = bands, C = centromere. – *Fig. 5 (right).* C-banded idiogram of a female European roe deer (*Capreolus capreolus* L.)